# Total Dose Performance of Radiation Hardened Voltage Regulators and References

S. S. McClure, J. L. Gorelick, R. L. Pease, B. G.Rax, R. L. Ladbury

*Abstract*--**Total dose tests of commercially available radiation hardened bipolar voltage regulators and references show reduced sensitivity to dose rate and varying sensitivity to bias under exposure. Behavior of critical parameters in different dose rate and bias conditions is compared and the impact to hardness assurance methodology is discussed.**

## I. INTRODUCTION

Previous tests of bipolar low dropout voltage regulators showed Enhanced Low Dose Rate Sensitivity (ELDRS) as well as significant bias effects [1], [2]. The physical mechanisms for this effect have been proposed [3]-[5]. In this work, four commercially available vendor radiation hardened microcircuits were tested at high [~ 50 rad($SiO_2$)/s] and low [0.01 to 0.05 rad($SiO_2$)/s] dose rates, with and without bias during exposure. Two of the devices tested were comparable voltage references, one was positive voltage regulator, and the last, a positive low dropout voltage regulator. The purpose of these tests was to determine if the devices were subject to degradation similar to other regulators and references and to assess suitability for use in space systems. The desire was to find devices which were capable of functioning to greater than 100 krad and to determine if these processes were subject to ELDRS effects. A further objective of these tests was to determine the environment and bias condition suitable for radiation lot acceptance testing. It should be noted, however, that these tests were not intended to bound device performance at low dose rates. In general, it is recommended to perform tests at several 'low' dose rates to determine if degradation continues to increase at even lower dose rates.

Not all of the devices exhibited enhanced degradation at low dose rate. All were found to have some degree of bias sensitivity.

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Steven S. McClure and Bernard G. Rax are with the Jet Propulsion Laboratory, Pasadena, CA 91109 USA (telephone: 818-354-0482, e-mail: steven. s.mcclure@jpl.nasa.).

Jerry L. Gorelick is with Boeing Space Systems, El Segundo, CA 90245 USA (telephone: 310-364-8585, e-mail: jerry.gorelick @hsc.com).

Ron Pease is with RLP Research, Albuquerque, NM, USA.

Ray Ladbury is with Orbital Sciences Corporation, McLean, VA, USA.

## II. DEVICE DESCRIPTIONS

Tested devices are identified in Table I. All devices were obtained directly from the manufacturer.

## III. EXPERIMENTAL DETAILS

### A. *Total Dose Facilities*

Total dose irradiations for the HS1009 and RH1009 were performed at the high and low dose rate Co-60 range sources at the Jet Propulsion Laboratory, Pasadena, CA. Total dose irradiations for the L4913 and HS117 were performed at the Raytheon Component Evaluation Center, El Segundo CA. At this facility, low and high dose rate irradiations were preformed using a Shepherd model 142 and a Gammacell 220 Co-60 irradiator respectively. Dose rates for the high dose rate exposures ranged between 50 and 62 rad/s. Low dose rate exposures were carried out at between 0.01 to 0.05 rad/s. All sources were in compliance with MIL-STD-883, Method 1019, and have undergone dosimetry correlation [6].

### B. *Electrical Tests*

All electrical tests, for parts tested at Raytheon in El Segundo, CA, were performed using an LTX automated test system. Electrical tests for parts tested at JPL were performed using an LTS2020. Irradiations and electrical tests for each device type were performed at the same location. Electrical tests included all of the DC test parameters in the manufacturer's specification.

### C. *Procedure*

Samples of each device type were divided into four groups of three to four parts each for biased and unbiased low rate as well as biased and unbiased high rate irradiations. Exception to this was the RH1009, where there was no unbiased high dose rate group. After pre-irradiation electrical tests, the four groups underwent step level irradiation and test. The time between irradiation steps for electrical tests was between one to two hours. The outputs of the biased samples were periodically monitored on the bias circuit to ensure that the devices were stable while under irradiation. The time frame for group tests for each device type was maintained as short as possible; i.e. months did not pass between high and low dose rate tests. This was done to minimize any error due to equipment calibration changes. The irradiation bias

TABLE I
IDENTIFICATION OF TESTED PART TYPES

| Generic | Part Number | Date Code | Die Manufacturer | Description | Procured as |
|---|---|---|---|---|---|
| RH1009 | RH1009 | 9825 | Linear Technology | 2.5V Precision Reference | S-level |
| HS1009 | HS1009 | 00xx[a] | Intersil | 2.5V Precision Reference | Engineering samples |
| HS117 | HSYE-117RH/ PROTO | 00xx[a] | Intersil | 1.5A Positive Adjustable Voltage Regulator | Engineering samples |
| L4913 | L4913 | H942199 | ST Microelectronics | Low Dropout Positive Adjustable Voltage Regulator | Engineering samples |

[a] Engineering samples provided with no date code
[b] Commercial chips in hermetic flight package

conditions for biased irradiations are defined in Table II. Parts in the unbiased groups had all leads shorted.

TABLE II.
IRRADIATION BIAS CONDITIONS

| Device | Bias conditions |
|---|---|
| RH1009 | 1mA thru 12.4Kohm |
| HS1009 | 1mA thru 12.4Kohm |
| HS117 | Vin = 15V, Vout = 10V, Iout = 10 mA |
| L4913 | Vin = 10V, Vout = 6V, Iout = 100 mA |

## IV. TEST RESULTS

### A. RH1009

As shown in Fig.s 1 and 2 this device showed no sensitivity to dose rate for the biased condition. Device did however exhibit bias dependency at low dose rate with more degradation for the unbiased condition, particularly at the 10 mA operating condition. The manufacturer's post radiation specifications were met under all tested irradiation conditions.

### B. HS1009

Low dose rate tests for this device are presently at 300 Krad, with plans to continue to 1000 Krad. Data at this point, Fig. 3, indicates that the device is bias sensitive but does not exhibit ELDRS.

### C. HS117

This device exhibited ELDRS with maximum output current degrading more rapidly for the low dose rate condition (Fig. 4). Reference voltage for this device exhibited both an enhancement at low dose rate as well as a bias dependence (Fig. 5), the unbiased low dose rate case being the worst performer. It should be noted however that all devices tested passed to the manufacturers specification at the dose levels tested.

### D. L4913

Low dose rate testing of the device is presently continuing beyond 60 Krad at this time. At this point the device has exhibited significantly better total dose performance and a much reduced ELDRS effect in comparison with comparable positive LDO regulators. As shown in Fig. 6, for this device no ELDRS or bias effects are indicated at this point for the reference voltage. For dropout voltage and maximum output current (Fig.s 7, 8), unbiased low rate condition appears to be the worst case.

## V. DISCUSSION

It was noted for both of the references that though a bias sensitivity was found, low dose rate sensitivity was not found. In the case of the regulators, both had some degree of low dose rate enhancement, though the increase in degradation at low dose rate was far less than that found in comparable non-radiation hardened devices. The complete paper will expand on the parametric effects for each device and identify the point at which the device began to exceed specifications.

## VI. CONCLUSIONS

It is clear that the manufacturer's radiation hardened processes used to fabricate these devices resulted in a significant reduction in ELDRS effects. This will be expanded upon in the completed paper with comparison with data on the non-radiation hardened equivalent devices. Where possible, the completed paper shall included data on the manufacturers process.

## VII. REFERENCES

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[5] D.M. Fleetwood, "Physical mechanisms contributing to enhanced bipolar gain degradation," IEEE Trans. Nucl. Sci., vol. 41, p. 1871, 1994.
[6] M. Simons, et al., "Common-source TLD and RADFET characteristics of Co60, Cs137, and x-ray irradiation sources,' 1997 IEEE Radiation Effects Data Workshop Record, p. 28, 1997.

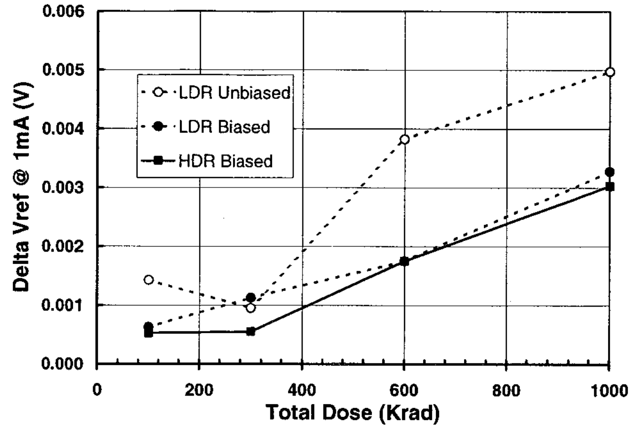


Figure 1. RH1009 Change in Vref @ 1mA

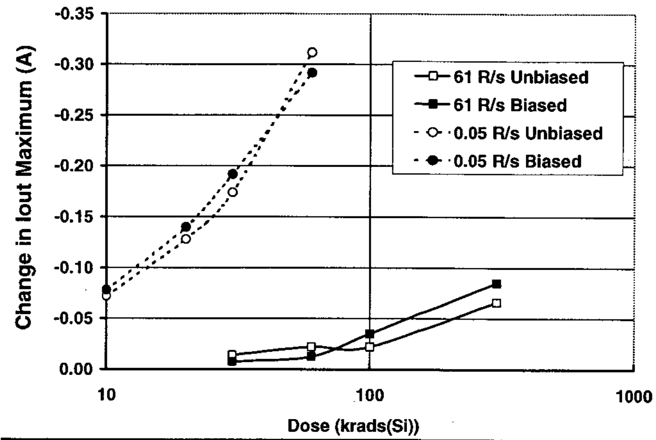


Figure 4. HS117 Change in maximum output current

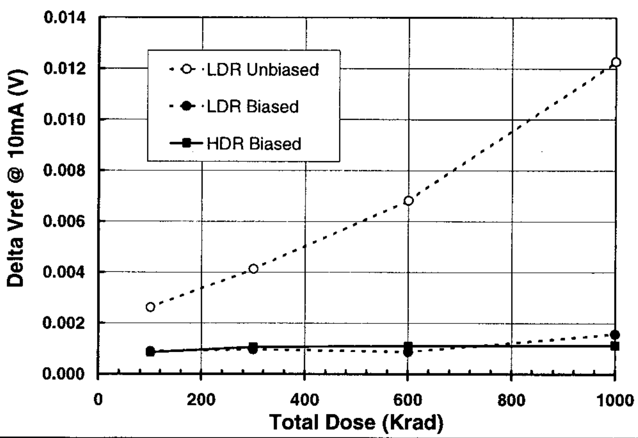


Figure 2. RH1009 Change in Vref @ 10mA

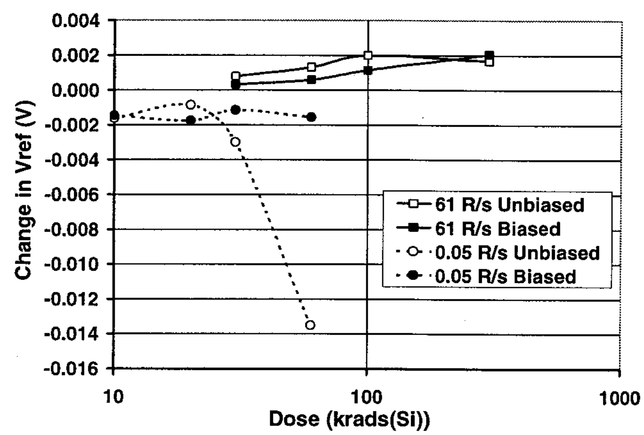


Figure 5. HS117 Change in maximum reference voltage

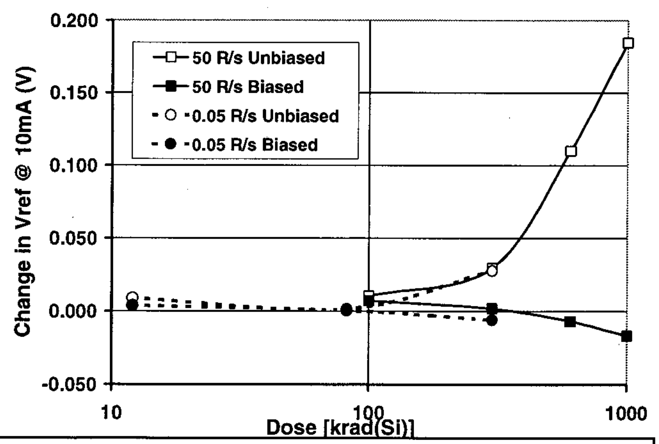


Figure 3. Intersil HS1009 Change in Vref @ 10mA

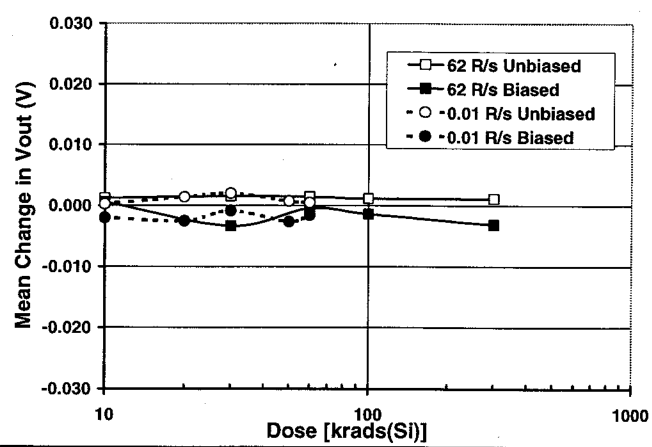


Figure 6. L4913 Change in ouput voltage (Vref)

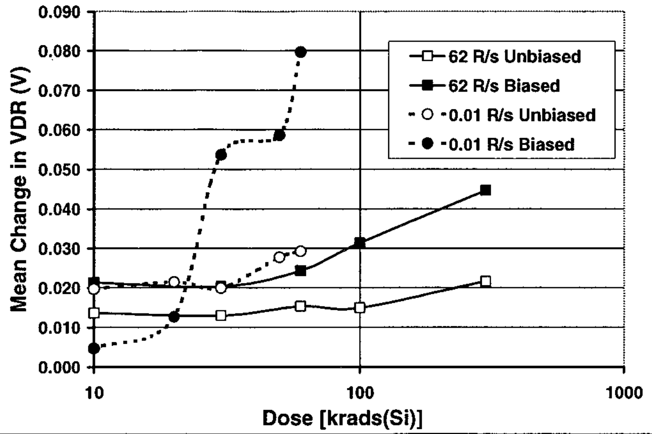


Figure 7. L4913 Change dropout voltage

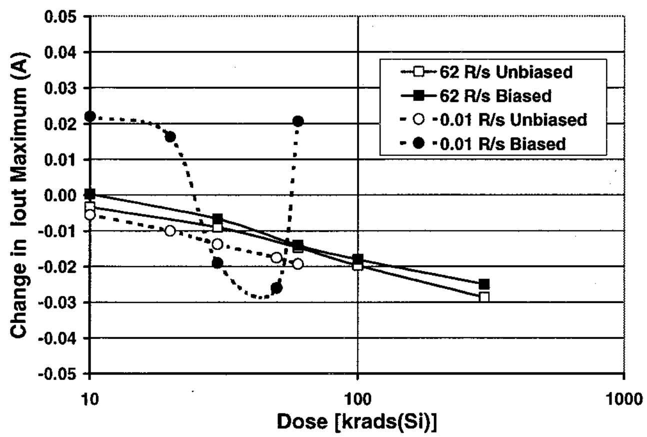


Figure 8. L4913 Change in maximum output current